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Anatomy of the hip: correlation of coronal and sagittal cadaver cryomicrosections with Magnetic Resonance Images

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Summary. Magnetic resonance imaging (MRI) is noninvasive and provides images with higher soft tissue contrast than possible with any other imaging modality. Unlike CT which depicts anatomy in the axial plane, MRI is capable of producing images in thin cross sections acquired directly in any plane, usually axial, coronal or sagittal planes. The use of diagnostic MR images is facilitated by an understanding of the detailed anatomy that is depicted. The purpose of this study was to identify anatomical structures in coronal and sagittal cryomicrosections of the hip region. Thin cryosections of the hips of fresh-frozen cadavers were obtained by a method developed by one of the authors (WR). These sections were matched with thin-section, high resolution MR images of a normal volunteer. The complex anatomy of the hip and its surrounding muscles, tendons and ligaments was exquisitely depicted on both the cadaver microcryosections and the matched MRT images.

Offprint requests : LW Bassett

Anatomie de la hanche : corrélation entre les microsections et les résultats de l'imagerie en résonance magnétique

Résumé. L'imagerie en résonance magnétique (IRM) est une technique non invasive qui permet d'obtenir des images des parties molles avec un contraste plus élevé que toutes les autres techniques. A la différence du scanner qui décrit l'anatomie dans le seul plan axial transverse, l'IRM est capable de donner des images en coupes fines obtenues directement dans n'importe quel plan : couramment dans les plan axial, transverse et sagittal. L'interprétation des images IRM est facilitée par la compréhension de l'anatomie détaillée de la région étudiée. Le propos de ce travail est d'identifier les structures anatomiques dans des plans de coupes sagittales et coronales de la région de l'articulation coxo-fémorale. Des coupes fines de pièces congelées ont été obtenues à partir de douze cadavres selon une méthode mise au point par l'un des auteurs (WR). Ces sections ont été comparées avec des coupes IRM fines faites en haute résolution chez un volontaire sain. L'anatomie complexe de la hanche et des muscles qui l'entourent ainsi que des tendons et des ligaments est décrite avec précision sur les coupes anatomiques et les images IRM.

Key words: Hip — Anatomy — Cryomicrotomy - Magnetic resonance imaging

Magnetic resonance imaging (MRI) has several advantages over other methods in the depiction of the anatomy of the musculoskeletal system [7, 9, 12, 16]. Cross-sectional anatomy of the hip joint in the axial plane has been correlated with CT images [4, 6, 8,13-15]. CT is capable of producing thin section images, with higher soft tissue contrast than conventional radiography. CT images, acquired directly in the axial plane, have proven useful in the evaluation of fractures around the hip joint [13]. Due to the different MR signal intensities of fat and bone marrow, joint fluid, muscles, tendons and ligaments, and blood vessels, MR imaging provides

Table 1. Signal characteristics of musculoskeletal tissues in T1-weighted MR images
Caractéristiques des signaux des tissus de l'appareil musculo-squelettique en séquence pondérée T1

Tissue	Signal Characteristics
Cortical bone	Void
Ligaments, tendons	Void
Fibrocartilage	Void
Normal fluid	Low
Muscle	Intermediate
Hyaline cartilage	Intermediate
Fat (including marrow)	High

higher soft-tissue contrast than CT (Table 1). As a result, MRI is proving useful in the evaluation of tumors, trauma and infection involving joints, muscles and tendons, and it is an extremely sensitive indicator of bone marrow abnormalities [1, 2, 5, 16, 17]. Unlike CT, thin-section MR images can be acquired directly in coronal, sagittal or any oblique planes, as well as in the axial plane.

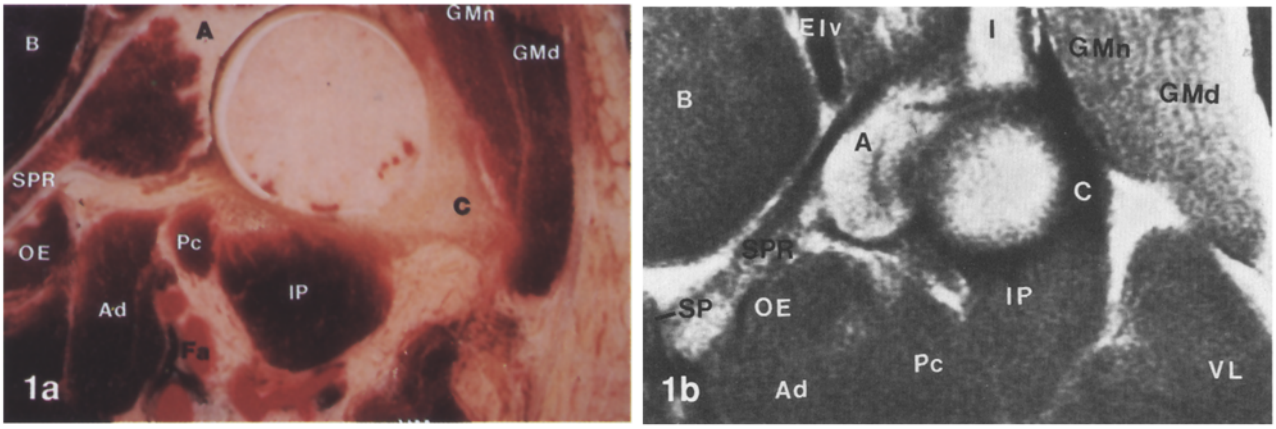
In order to better understand the anatomy of the hip in coronal and sagittal images, we acquired thin-section, high-resolution MR images of the hip of a normal volunteer and correlated the anatomy with matched cadaver cryomicrosections.

Material and Methods

The cryomicrosections were obtained using a method developed in Sweden by one of the authors (WR) [9, 11]. In order to aid in their identification, the arteries of fresh cadavers were injected with a red pigmented barium compound with pulsatile, hypersystemic pressure prior to freezing. This injection forced all blood into the venous sytem, slightly distending the veins. The bladder was injected with blue-tinted saline. The region of interest was resected with an oscillating band saw, embedded in a car-

Figs. 1-4
Figs 1-4 are coronal cryomicrosections and MR images arranged from anterior to posterior. **1** Coronal cryomicrosection (A) and matched MR image (B) at the level of the anterior aspect of femoral head. The femoral artery and its branches are filled with red pigment in the cadaver section and the bladder contains a dark blue pigment. In the MR image, the external iliac vessel is seen as a signal void and the thick fibrous capsule of the hip also has no signal. The cortical bone of the superior pubic ramus is a signal void but the bone marrow has a high signal intensity. The symphysis pubis is at the left side of the image. The muscles have intermediate signal intensity, and their locations can be identified although the borders of each muscle cannot always be defined in the MR image **2** Coronal cryomicrosection (A) and MR image (B) at the midportion of the femoral head and neck. The femoral head marrow has high signal intensity except at three localized regions: the fovea capitis, the horizontally oriented physeal scar (*arrow*), and the prominent trabeculae in the lines of stress. The medial aspect of the hip joint is identified by the acetabular tear drop. The profunda femoris a. can be seen in both the cryomicrosection and the MR image. The musculotendinous junction of the gluteus minimus can be identified in the MR image where the signal intensity changes from an intermediate intensity to a signal void. The internal and external branches of the iliac artery are identified at the top of the MR image. The hyaline cartilage can be identified as an intermediate signal intensity structure lying between the signal void of the cortical and acetabular cortical bone **3** Coronal cryomicrosection (A) and MR image (B) at the level of the anterior aspect of the lesser trochanter. The course of the obturator externus m. and its tendon is seen, from its origin (on the margin of the obturator foramen) to its tendinous insertion (at the posterior aspect of the hip joint along the digital fossa of the femur). The gluteus minimus is seen with its tendon inserting on the greater trochanter **4** Coronal cryomicrosection (A) and MR image (B) at the most posterior aspect of the greater and lesser trochanter. Three of the muscles that insert on the posterior aspect of the greater trochanter, the piriformis, superior gamellus and inferior gamellus can be distinguished in both the cryomicrosection and the MR image

Les figures 1 à 4 sont des coupes coronales, elles sont classées d'avant en arrière. Coupe anatomique : A, coupe IRM : B. **1** Coupe passant par le pôle antérieur de la tête fémorale. L'a. fémorale et ses branches sont colorées en rouges sur la coupe cadavérique, la vessie est colorée en bleu foncé. En IRM les vaisseaux iliaques externes sont représentés par un signal vide, l'épaisse capsule articulaire de l'articulation coxo-fémorale n'a pas, elle non plus de signal IRM. L'os cortical de la branche ilio-pubienne a un signal nul, la moelle osseuse par contre possède un signal élevé. La symphyse pubienne se situe à gauche de l'image. les muscles possèdent un signal intermédiaire, il peuvent être localisés bien que leur limites ne soient par parfaitement définies en IRM **2** 3 coupes passant par la portion moyenne de la tête et du col fémoral. La moelle de la tête fémorale possède un signal élevé sauf dans trois régions précises: la fossette du ligament rond, le reliquat du cartilage épiphysaire (*flèche*) et les lignes de force de l'os spongieux. La face interne est identifiée grâce au sourcil cotyloïdien. L'a. fémorale profonde est visible sur les deux coupes. La jonction musculo tendineuse du petit fessier peut être identifiée sur la coupe IRM par le changement de signal qui d'intermédiaire devient vide. Les branches interne et externes de l'a. iliaque sont identifiables en haut de l'image IRM. Le cartilage hyalin est visible sous forme d'un signal intermédiaire situé entre le signal vide de la corticale de la tête fémorale et l'os cortical acétabulaire **3** Coupes passant juste en avant du petit trochanter. On peut voir le trajet de l'obturateur externe et son tendon depuis son origine au foramen obturé jusqu'à son insertion dans la fossette digitale du fémur **4** Coupes passant juste en arrière du grand et du petit trochanter. Trois des muscles qui s'insèrent à la face postérieure du grand trochanter peuvent être vus : le piriforme, le jumeau supérieur et le jumeau inférieur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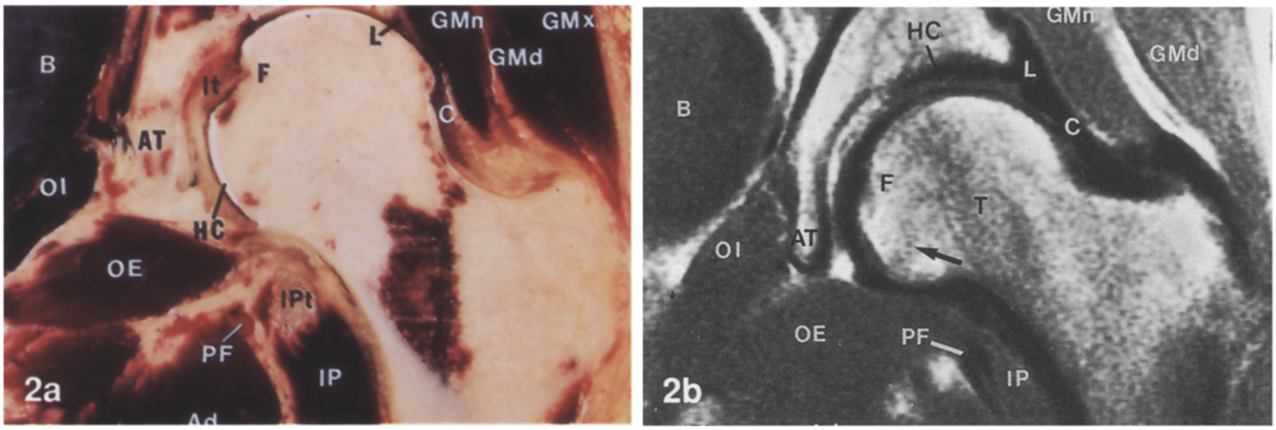
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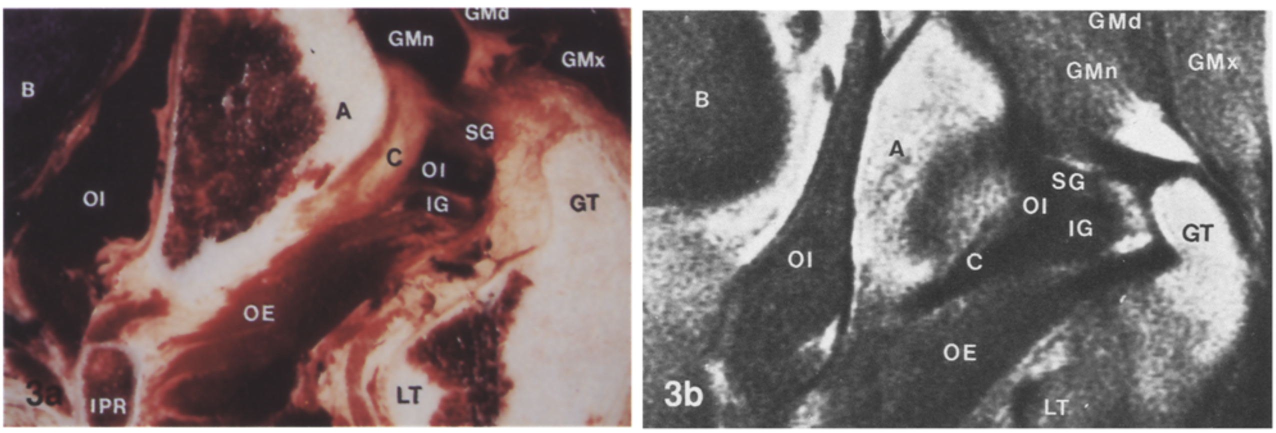
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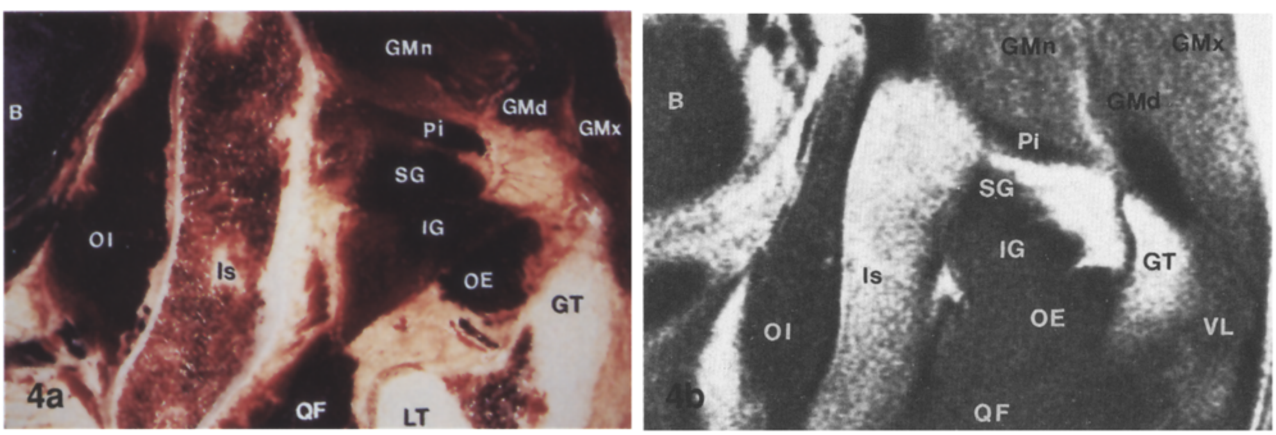
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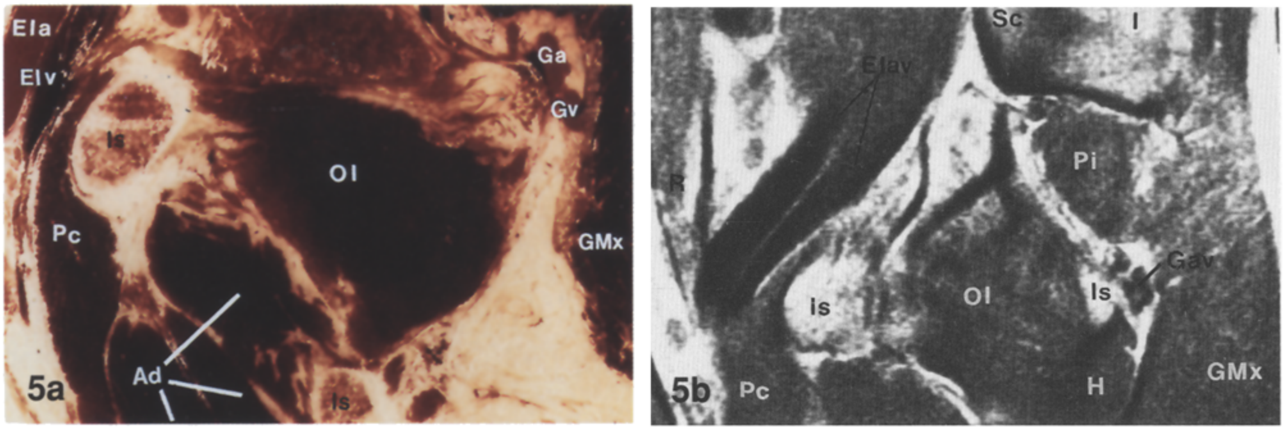
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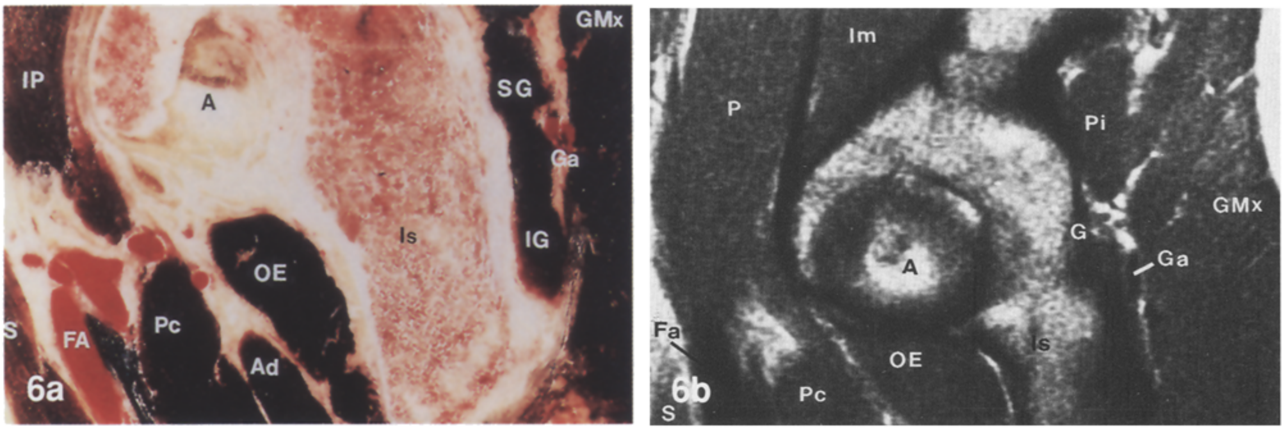
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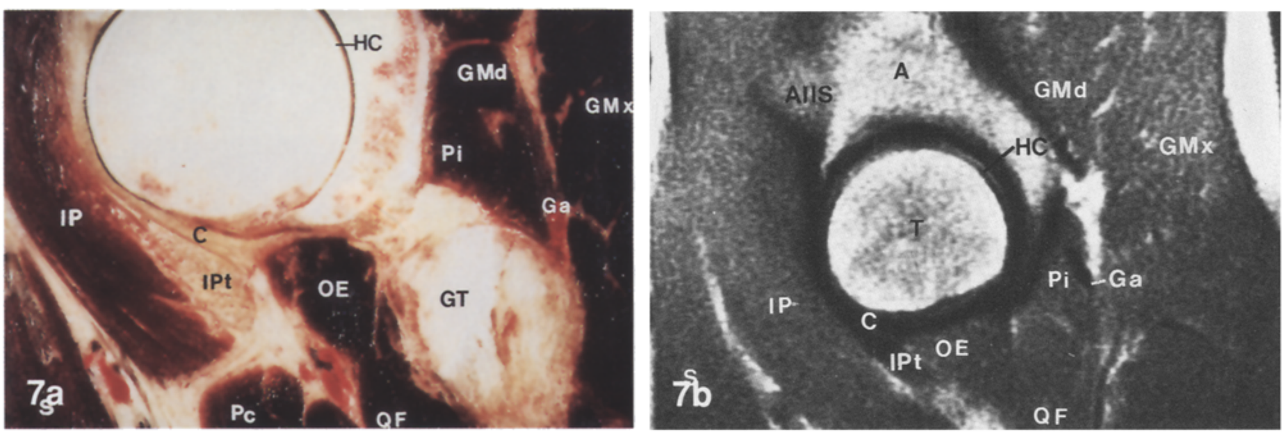
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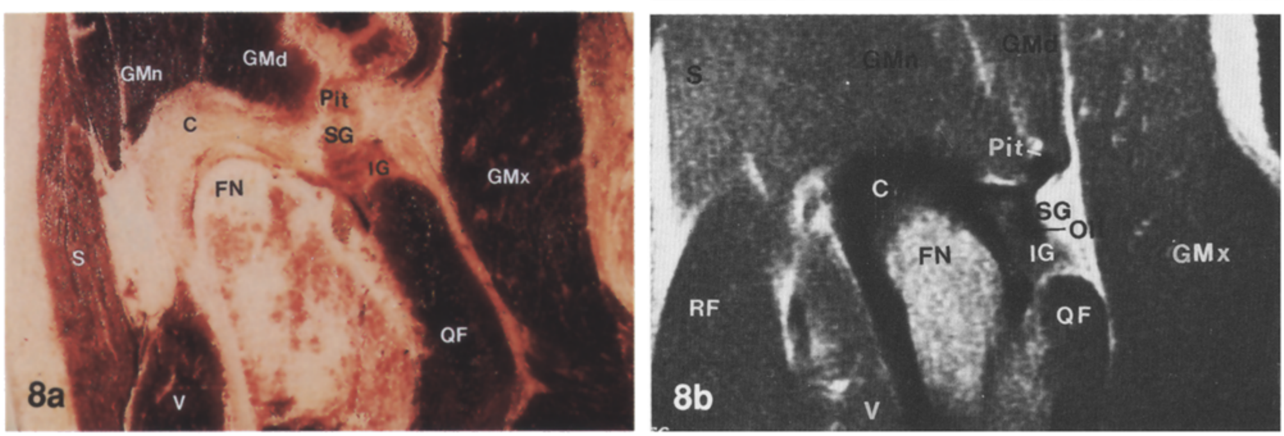
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boxymethyl cellulose gel, and then transferred to a heavy duty sledge cryomicrotome for sectioning. The frozen specimens were cryoplaned at 20 to 40 micron intervals. A specially designed camera stand which attached to the knife holder provided stable sequential photography of the surfaces of the cryoplaned specimen. The size of the cadaver specimens was limited by the 16 cm by 45 cm dimensions of the embedding frame.

MR images of a normal volunteer were acquired using a 0.3 T iron-core resistive magnet (Fonar, Melville, New York). Each coronal and sagittal MR image had a 7 mm thickness and was acquired at 10 mm intervals using a relatively T1-weighted pulse sequence (Spin Echo: 700 0.75 mm by 0.75 mm pixel size). The field of view for the MR images was 20 cm by 20 cm.

Results

Figures 1-4 show the coronal cryomicrosections and matched MR images, from anterior to posterior. Figures 5-8 show the sagittal cryomicrosections and matched MR images, from medial to lateral.

MR images depicted the normal anatomy of the hip with excellent detail. In particular, muscles and their tendinous insertions could be identified in coronal and sagittal planes. The MR appearance of the bony structures was as expected: cortical bone had no signal (black) and the marrow had a very bright signal (white) on this T1-weighted pulse sequence (Table 1). The hip capsule, ligaments and tendons had very low to absent signal intensity, which allows for their differentiation from adjacent muscles, which have intermediate signal intensity. Blood vessels were seen as signal void due to the rapid flowing blood. Hyaline cartilage had intermediate to high signal intensity in the

Figs. 5-8
Figures 5-8 are sagittal cryomicrosections and MR images arranged from medial to lateral **5** Sagittal cryomicrosection (A) and MR image (B) medial to the acetabulum, at the origin of the obturator internus on the ischial ramus. The external iliac a. is identified in the microcryosection by the red dye in its lumen and in the MR image by the tubular signal void of the rapidly flowing blood in its lumen **6** Sagittal cryosection (A) and MR image (B) at the level of the acetabular fossa. The femoral artery is visualized at the level of its bifurcation into deep and superficial branches. In the MR image, the two parts of the iliopsoas m., the psoas and iliacus muscles are clearly seen **7** Sagittal cryomicrosection (A) and MR image (B) at the midsection of the femoral head. The sartorius m. is seen most anteriorly. The anterior inferior iliac spine, site of origin of the rectus femoris is seen above the hip joint. The hyaline cartilage has intermediate to high signal intensity in the MR image. The thicker trabeculae of the femoral head are seen as low signal intensity structures within the high signal of the bone marrow **8** Sagittal cryomicrosection (A) and MR image (B) at the level of the femoral neck, near the greater trochanter. The distal aspects of the muscles and tendons of the piriformis, superior gemellus, inferior gemellus and obturator internus are identified near their insertions on the superior border of the greater trochanter

Les figures 5 à 8 sont des coupes dans plan sagittal, elles sont classées d'arrière en avant **5** La coupe passe par la partie interne de l'acétabulum à l'origine de l'obturateur interne et de la branche ilio-pubienne. L'a. iliaque externe est identifiée sur la coupe anatomique par la coloration rouge et sur l'IRM par un signal nul de forme tubulaire du au flux sanguin rapide **6** La coupe passe au niveau de la fossette acétabulaire. L'a. fémorale est visualisée au niveau de sa bifurcation. Sur les images IRM les deux portions du m. iliopsoas sont bien individualisées **7** Coupe passant par le milieu de la tête fémorale. Le m. couturier est le plus antérieur. L'épine iliaque antéro-inférieure, site d'insertion du droit fémoral surplombe l'articulation coxo-fémorale. le cartilage hyalin possède un signal intermédiaire. les travées les plus épaisses de la tête fémorale sont vue sous forme d'un signal de faible intensité au sein du signal élevé de la moelle osseuse **8** Coupe passant au niveau du col fémoral proche du grand trochanter. Les extrèmités distales des corps et des tendons des mm. piriforme, jumeau supérieur et inférieur ainsi que l'obturateur interne sont identifiables à proximité de leurs insertions au bord supérieur du grand trochanter

Key to abbreviations used in Figures. *A* acetabulum *Ad* adductor mm. *AdM* adductor magnus m. *AIIS* anterior inferior iliac spine *AT* acetabular tear drop *B* bladder *C* capsule of hip joint *EIa* external iliac a. *EIv* external iliac v. *EIav* external iliac a. and v. *EO* external oblique m. *F* fovea *Fa* femoral a. *FN* femoral neck *G* gemellus m.*Ga* gluteal a.*Gav* gluteal a. and v. *GMd* gluteus medius m.*GMn* gluteus minimus m. *GMx* gluteus maximus m. *GT* greater trochanter*Gv* gluteal v. *H* hamstring m. group *HC* hyaline cartilage *I* ilium *IIav* Internal iliac a./v. *IIv* Internal iliac v. *Iva* Iliac v. and a. *IG* inferior gemellus m. *IPt* Iliopsoas tendon *IO* internal oblique m. *Im* iliacus m. *IP* iliopsoas m. *IPR* inferior pubic ramus *Is* ischium *L* labrum *LT* Lesser trochanter *lt* ligamentum teres *OE* obturator externus m. *OI* obturator internus m. *OIt* obturator internus tendon *Pi* piriformis m. *Pit* piriformis tendon *Pc* pectineus m. *PF* profunda femoris a. *QF* quadratus femoris m. *R* rectus abdominus m. *RF* rectus femoris m. *S* sartorius m. *Sc* sacrum *SG* superior gemellus m. *SI* sacroiliac joint *SP* symphysis pubis *SPR* superior pubic ramus *T* trabeculae *V* vastus medialis mm. *VL* vastus lateralis m.

images, allowing its differentiation from the adjacent cortical bone of the acetabulum and femoral head which was seen as a signal void.

Discussion

Today, one of the major clinical applications of the study of gross anatomy is the correlation with diagnostic images [4, 7-9, 11-15]. The study of anatomy has become more complex as new imaging modalities have created a need to evaluate high-resolution cross-sectional images performed in multiple planes.

CT depicts anatomy directly in the axial plane, and the widespread use of CT has resulted in greater familiarity with cross-sectional anatomy in this plane. In addition to the axial plane, coronal and sagittal planes are frequently utilized for MRI, and MR images can be acquired directly in virtually any plane. The high soft-tissue contrast of MR images allows for the better distinction between soft-tissue structures such as bone marrow, joint fluid, and ligaments and tendons (Table 1).

MRI can be a useful diagnostic tool for evaluation of abnormalities in the region of the hip joint, including ischemic necrosis of the femoral head, tumors, infection, and injuries [1]. MRI has been shown to be useful in understanding the complex anatomy of the neonatal hip [3]. Hopefully, these matched cryomicrosections and MR images will be useful as an anatomical reference guide when evaluating the hip joint with diagnostic MR images.

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